Chapter Six: Specific Issues Related to Oil and Gas Exploration, Development, Production and Transportation

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A. Geophysical Hazards

There are three identified types of geophysical hazards within the Nenana basin study area. These include earthquakes and faulting; permafrost and frozen-ground phenomena; and flooding, ice, current, and sediment hazards. These geophysical hazards may constrain exploration, production, and transportation activities associated with possible petroleum exploration and development, and should be considered prior to locating, design or construction of related facilities in this area.

1. Earthquakes and Faulting

There is one major fault within the area of the Nenana basin identified by Kirschner (1994): the Minto Fault. The Minto fault, a northeast–southwest trending normal fault, forms the eastern edge of the Nenana basin structure. This fault roughly parallels the topographic ridges consisting of quartz- and pelitic-schist along the east edge of the basin. The Minto fault is largely covered by Quaternary surficial deposits of the Minto Flats area that blanket the entire basin. Evidence of the Minto fault comes from the earthquake epicenters forming a northeast-southwest trend in the area and the alignment of this trend with a magnetic trend seen in the subsurface.

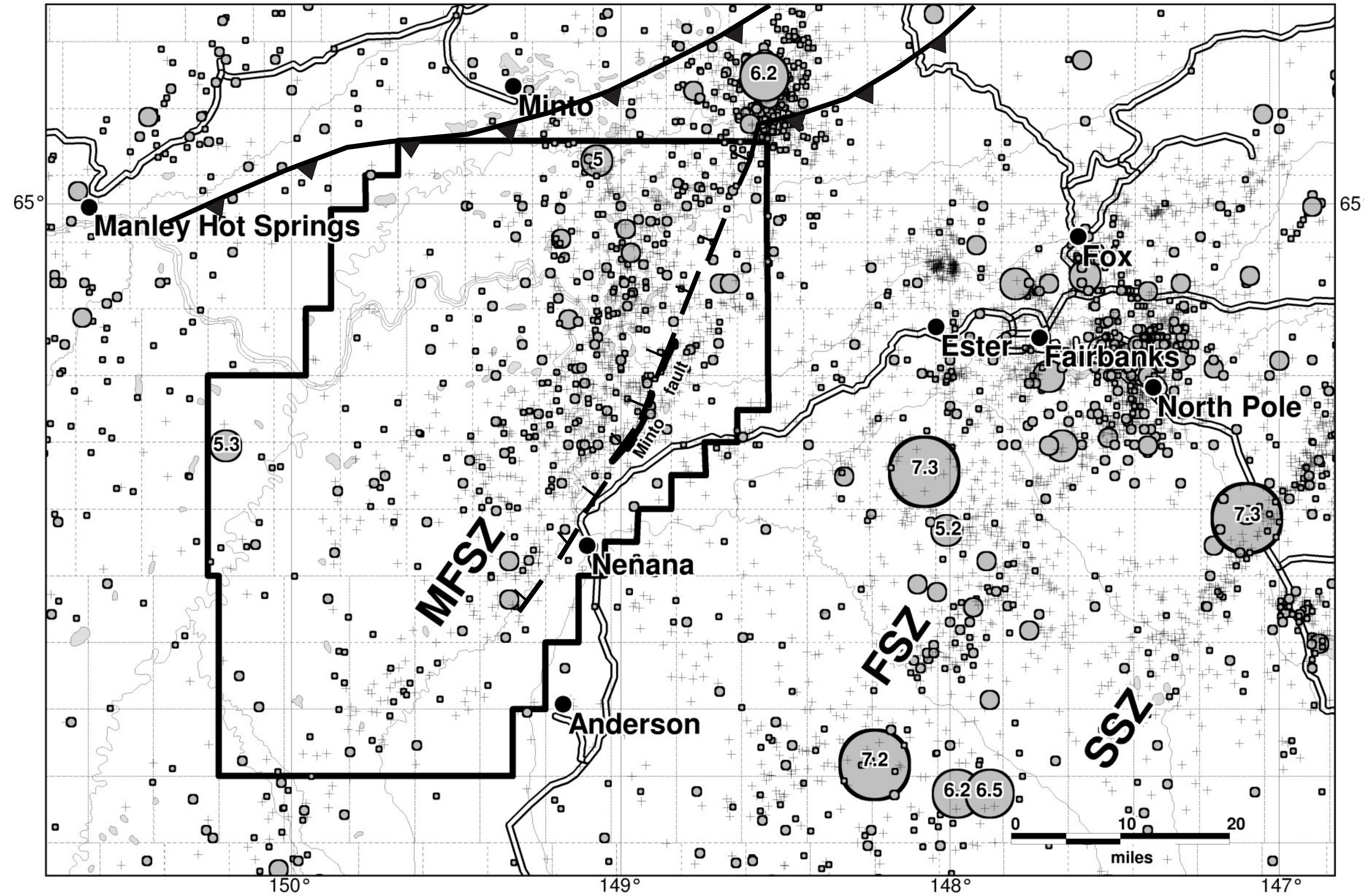
The compilation of earthquake epicenters seen in Figure 6.1 indicates a history of relatively minor earthquakes only reaching magnitudes as great as 5.3 in the study area. Earthquakes above magnitude 5.5 are considered to be potentially damaging. Outside of the study area, 15 miles to the east, earthquakes as large as magnitude 7.3 have been recorded. These moderate earthquakes are not expected to cause any significant damage in the study area. However, strong earthquakes may cause localized liquefaction features within the unconsolidated deposits of the Nenana basin. Other effects may include horizontal movement of vibration-mobilized soil, fissuring, and associated sand extrusions typical of areas where the ground surface is frozen. Structures in the study area must be built to meet or exceed the Uniform Building Code requirements for zone 4, areas of high earthquake probability.

2. Permafrost and Frozen-Ground Phenomena

Most of the study area is underlain by discontinuous permafrost that is highly susceptible to thermal degradation. Permafrost is defined as soil, rock, or any other earth material whose temperature remains below freezing continuously for two or more years. Most of the permafrost in Alaska has been in existence for many thousands of years. The presence of permafrost depends upon the glacial and climatic history, the thermal properties of the local sediment and rock, and the insulating properties and thermal balance of material at the ground surface. The factors that control the distribution of permafrost also control its temperature, which varies markedly with depth, latitude, and geologic and topographic setting. Large, deep bodies of water (rivers, lakes, and oceans) also affect soil temperatures.

During the winter months, thermal contraction of the ground surface may cause it to crack in a pattern resembling mud cracks, only much larger. Summer meltwater pours into these cracks in the permafrost and

FIGURE 6.1



HISTORIC SEISMICITY OF THE NENANA BASIN STUDY AREA AND VICINITY THROUGH FEBRUARY 2001

Nenana Basin Study Area

MFSZ - Minto Flats seismic zone
FSZ - Fairbanks seismic zone
SSZ - Salcha seismic zone

Thrust Fault
(Teeth On Upper Plate)

Inferred Normal Fault
(Hachuers On Downthrown Block)

Magnitude
- 7.0 - 7.9
- 6.0 - 6.9
- 5.0 - 5.9
- 4.0 - 4.9
- 3.0 - 3.9
- 2.0 - 2.9
- Less than 2

Data from Alaska Earthquake Information Center, University of Alaska Fairbanks
Figure by R.A. Combellick, Alaska Division of Geological & Geophysical Surveys

Source: Combellick 2001, Kirschner 1994.

freezes, forming a vertical network of intersecting ice veins. Repeated cracking at points of weakness causes these veins to grow into a network of massive ice wedges, which are sometimes indicated by polygonal-shaped ground surface markings. Some ice wedges are the products of ancient climates that are preserved in permafrost at considerable depths.

The Nenana basin is characterized by moderately thick to thin permafrost in areas of fine-grained deposits, and by discontinuous or isolated masses of permafrost in areas of coarse-grained deposits. Engineering modifications of the environment can cause thawing of permafrost in two ways. The first is by changing the seasonal thermal balance at the surface, which can be caused by gravel pads, damage to the organic surface layer, or disrupted surface drainage. The second type of modification results from heated buildings or uninsulated buried pipelines conveying material at temperatures warmer than the surrounding soil. The primary engineering problems resulting from thawing of permafrost relate to its potential loss of strength and volume. This can cause severe differential settlement or loss of bearing strength, which would affect roads, pads, and foundations.

Site-specific geotechnical studies should be conducted prior to any development activities to assess the local permafrost conditions, so the most cost-effective engineering modifications can be included during the design phase of the planned development. Permafrost problems can be mitigated through proper siting, design, and construction considerations. Structures, such as drill rigs and permanent facility buildings, should be insulated to prevent heat loss into the substrate. Pipelines can be trenched, backfilled, insulated (if buried), or elevated to prevent undesirable thawing of permafrost.

3. Flooding, Ice, Current, and Sediment Hazards

The Nenana basin is a relatively smooth plain, less than 1,000 feet in altitude, cut by the Tanana River and its tributaries. The Tanana River and most of its tributaries are formed from the runoff of precipitation in the Alaska Range on the south and the Yukon-Tanana Uplands to the north. The rivers primarily have braided courses. Thaw lakes are common throughout the basin.

Floods in this area are commonly caused by two mechanisms: ice jam flooding and excessive rainfall, both of which can cause seasonal flooding in the region.

Ice Jam Flooding: This type of flooding occurs during breakup when ice blocks a river or stream, in effect becoming a dam. This causes water to back up and flood the adjacent land. Ice jam flooding is localized, but affects the greatest number of residents over time because of the high population concentration along rivers.

Excessive Rainfall: The result of unusual combinations of extreme meteorological conditions and snowmelt may cause the rare occurrence of flooding in the region. Unusual conditions may include: the interaction of tropical moisture with a deep, low pressure system; blockage of the eastward movement of this tropical low by a high pressure ridge in eastern Alaska and/or western Canada; saturated soil conditions; and greater than normal snow or glacial melt due to preceding storms. In addition, excess sediment deposition in channels due to rapid runoff might decrease the carrying capacity of the streams.

Seasonal flooding of lowlands and river channels is extensive along the major rivers that drain into the study area. Thus, measures must be taken prior to facility construction and field development to prevent losses and environmental damage. Pre-development planning should include surveys of spring break-up activity, as well as flood-frequency analyses. Erosion rates, sediment grain-size and cohesiveness, and riverbank stability must also be considered in determining facility siting, design, construction, and operation. Structural failure can be avoided by proper facility setbacks from rivers and main tributaries.

As part of predevelopment planning, data should be collected on water levels, ice floe direction and thickness, discharge volume and velocity, and suspended and bedload sediment measurements for analysis. Also, historical flooding observations should be incorporated into a geophysical hazard risk assessment. Inactive channels of a river must be analyzed for their potential for reflooding. Containment dikes and berms might be necessary to reduce the risk of floodwaters that could undermine facility integrity.

B. Likely Methods of Transportation

1. Pipelines

Pipelines are the most likely method for transporting oil and gas from the study area. Since geologists believe that natural gas is more likely to be encountered in commercial quantities than is oil, the most likely scenario would involve constructing a pipeline system for natural gas to be made available to local markets in and near the study area and in the Fairbanks area. At the licensing phase however, it is impossible to predict the extent or location of new transportation facilities.

Gas pipelines use compressors to push natural gas through the lines after the gas has been treated. Separators isolate the components. Heaters prevent hydrate formation within the equipment. Dehydrators remove almost all of the water vapor. The piped gas is measured and monitored by a computer system that coordinates the operation of valves, prime movers and conditioning equipment. If a problem occurs, the computer initiates corrective actions and sounds alarms at the appropriate control points. Released gas would probably dissipate unless a spark sets it off. Ignition could result in a violent explosion. (University of Texas, 1986, pp. 297-301)

Gas pipelines are usually buried. An oil pipeline will be either elevated or buried depending on local soil conditions and other considerations such as movement of wildlife. An individual oil pipeline may alternate between buried and elevated, as is the case with the Trans-Alaska Pipeline System.

a. Elevated Pipelines

Elevated pipelines are typically used in Alaska to prevent heat transfer from the hot oil in the pipeline to frozen soils, since heat would degrade the permafrost. Elevated pipelines are easy to maintain and visually inspect for leaks. However, above-ground pipelines can restrict wildlife movements unless provisions are made to allow for their safe passage. In areas where pipelines must be placed above ground, they must be sited, designed, and constructed to allow free movement of moose and other terrestrial animals.

b. Buried Pipelines

Buried pipelines are the preferred method for transporting gas. They are feasible for transporting oil as long as the integrity of the frozen soils is maintained. There are some important considerations regarding long sections of buried pipe. First is cost, which depends on length, topography, soils, and distance from the gravel mine site to the pipeline. Second, buried pipe is more difficult to monitor and maintain. However, significant technological advances in leak detection systems have been made, which increase the ease with which buried pipelines can be monitored. These systems are described below. Third, buried pipelines may involve increased loss of wetlands because of gravel fill. Finally, buried pipelines are sometimes not feasible from an engineering standpoint because of the thermal instability of fill and underlying substrate (Cronin et al., 1994:10).

2. Oil Spill Risk

Any time crude oil or petroleum products are handled there is a risk that a spill will occur. Oil spills associated with exploration, development, production, storage, and transportation of crude oil may occur from well incidents (blowouts), pipeline spills, and chronic operational spills of low volumes involving fuels and other petroleum products associated with normal operation of drilling rigs and other facilities.

MMS has performed a quantitative oil spill analysis for North Slope onshore oil and gas exploration and development spills. While direct comparisons cannot be made with the Nenana basin, the North Slope experience may be useful in estimating likelihood of spills in the study area. The pattern of crude-oil spills that occurred on the North Slope is one of numerous small spills. Thirty-two percent of crude oil spills that occurred between 1989 and 1996 were less than or equal to 2 gallons. Fifty-six percent were less than or equal to 5 gallons. During that time period, no spill greater than 1,000 bbl occurred. The database spill size ranged from greater than 1 gallon to 925 bbl. The average crude oil spill is 3.8 bbl, and the median spill size is 7 gallons. The estimated crude oil spill rate for the North Slope is 199 spills per billion bbl produced (MMS, 1997:IV-A-31).

This information shows that most spills associated with exploration or production facilities are normally quite small, 5 bbl (210 gal) or less, and are usually related to everyday operations. Even a worst-case oil discharge from an exploration facility, production facility, or pipeline is restricted by the maximum storage capacity or the well's ability to produce oil. For example, a well with a maximum production rate of 2,500 bbl per day will only spill a maximum of 2,500 bbl per day (Powers, 1989:2). As another example, a 14-inch pipeline can store approximately 1,000 bbl of oil per mile of pipeline length. Accordingly, under static conditions if oil were lost from a five-mile stretch of pipeline (a hypothetical distance or spacing between emergency block valves), then a maximum of 5,000 bbl of oil is all that would be discharged into the environment.

The state has enacted stringent oil spill prevention, control, and cleanup legislation (AS 46.04.010-900). The statutes require oil spill contingency plans, which include methods for detecting, responding to, and controlling blowouts; prevention, control, and cleanup plans; and location and identification of cleanup equipment.

The risks associated with producing and transporting oil can never be reduced to zero. There is always some chance that spills will result from exploration, production, storage, and transportation of oil. However, the state's goal is to reduce the possibilities of spills to a level of acceptable risk and to improve the ability to respond to spills, should they occur.

C. Oil Spill Prevention

The technology for monitoring pipelines is continually improving. A number of leak detection systems are already in use or proposed for Alaska oil and gas pipeline development. Elements of these systems could be incorporated into any new oil pipelines constructed in the study area. Leak detection systems and effective emergency shut-down equipment and procedures are essential in preventing discharges of oil from any pipeline which might be constructed in the study area. Once a leak is detected, valves at both ends of the pipeline, as well as intermediate block valves, can be manually or remotely closed to limit the amount of discharge. The number and spacing of the block valves along the pipeline will depend on the size of the pipeline and the expected throughput rate (Nessim and Jordan, 1986:68). Industry on the North Slope currently uses the volume balancing method to determine this rate, which involves comparing input volume to output volume.

Leak detection methods include acoustic monitoring, pressure point analysis, and combinations of some or all of the different methods (Yoon, Mensik, and Luk 1988). The approximate location of a leak can be determined from the sensors along the pipeline. A computer network is used to monitor the sensors and signal any abnormal responses. In recent years, computer-based leak detection through a Real-Time Transient Model has come into use. This technology can minimize spills from both new and old pipelines (Yoon and Mensik, 1988a).

1. Pressure Point Analysis (PPA)

This method uses measured changes in the pressure and velocity of the fluid flowing in a pipeline to detect and locate leaks. PPA has successfully detected holes as small as 1/8-inch in diameter within a few seconds to a few minutes following a rupture (Farmer, 1989:23). Automated leak detection systems such as PPA operate 24 hours per day and can be installed at remote sites. Information from the sensors can be transmitted by radio, microwave, or over a hard wire system.

Three other systems can be employed which detect leaks down to 0.12 percent of rated capacity (100 bbl per hour). These include Line Volume Balance, Deviation Alarms, and Transient Volume Balance.

2. Line Volume Balance

LVB checks the oil volume in the pipeline every 30 minutes. The system compares the volume entering the line with the volume leaving the line, adjusting for temperature, pressure, pump station tank-level changes, and slackline conditions.

3. Deviation Alarms

There are three types of deviation alarms: pressure, flow, and flow rate balance. Pressure alarms are triggered if the pressure at the suction or discharge of any pump station deviates beyond a certain amount. Flow alarms are triggered if the amount of oil entering a pump station varies too much from one check time to the next. Flow rate balance alarms are triggered if the amount of oil leaving one pump station varies too much from the amount entering the next pump station downstream. This calculation is performed on each pipeline section about six times a minute.

4. Transient Volume Balance

TVB can both detect whether a leak may be occurring and identify the probable leak location by segment, especially with larger leaks. While the LVB leak detection system monitors the entire pipeline, the TVB system individually monitors each segment between pump stations. Since the TVB indicates in which area a leak may be occurring, focused reconnaissance and earlier response mobilization are possible (Alyeska Pipeline, 1999a).

5. LEOS

Another available detection system, LEOS (Leck Erkennung und Ortangs System), is a leak detection and location system manufactured by Siemens AG. The system has been in use for 21 years and in over thirty applications.

LEOS consists of a three-layer gas-sensor tube that is laid next to the pipeline. The inner layer is a perforated gas transport tube of modified PVC. A diffusion layer of EVA surrounds and allows gasses to enter the inner tube. A protective layer of braided plastic strips forms the outer layer. The tube is filled with fresh air, and the air is evacuated through a leak detector at regular intervals. If leak occurs, hydrocarbon gasses associated with the leak enter the tube and are carried to the gas detector. The system is totally computer controlled, self-checking and re-setting. Background gasses are calibrated at setup and checked regularly. The system will pick up previous contamination and organic decomposition. The location of the leak is determined by monitoring the time that leaked gas arrives at the detection device.

The system is very low maintenance and will last the life of the pipeline. Special protective adaptations will be made for the cold temperatures in which the system will operate and for the backfill installation method that will be used to install the pipeline. The tube will be placed in a protective cover, and the system will be tested continuously as the segments are installed. LEOS will be strapped to the oil pipeline next to the poly spacers that will separate the gas line from the oil line. The system will detect leaks from both lines, and operators will be able to tell the difference between the two. Engineers estimate that it will take about 5 to 6 hours for leaked molecules to migrate to the LEOS tube. The air inside the tube will be evacuated and tested every 24 hours

6. Smart Pigs

Design and use of "smart pigs," data collection devices that are run through the pipeline while it is in operation, has greatly enhanced the ability of a pipeline operator to detect internal and external corrosion and differential pipe settlement in pipelines. These pigs can be sent through the pipeline on a regular schedule to detect changes over time and give advance warning of any potential problems. The TAPS operation has pioneered this effort for Arctic pipelines. The technique is now available for use worldwide and represents a major tool for use in preventing pipeline failures.

7. FLIR

Phillips Petroleum utilizes a comprehensive FLIR (Forward Looking InfraRed) pipeline monitoring program in the Kuparuk oil field to assist in detecting pipeline leaks and corrosion. InfraRed sensors have the ability to sense heat differentials. Since Kuparuk oil flows from the ground at temperatures in excess of 100F, a leak shows up as a "hot spot" in a FLIR video. In addition, water-soaked insulation surrounding a pipeline is visible because of the heat transfer from the hot oil to the water in the insulation and finally to the exterior surface of the pipeline. FLIR is effective 80 percent of the time in discovering water-soaked insulation areas that have produced corrosion on the exterior wall of the pipeline (ARCO, 1998).

FLIR also has applications in spill response and was used to image spills at both Prudhoe Bay and Kuparuk. The video frames were processed and registered into a GIS map database. The map database with the overlaid picture of the spill site was then used to quickly and accurately determine the area of the spill. This action allowed swift and accurate reporting of the spill parameters to the appropriate agencies. The video footage of the spill area allowed the incident command team to receive near real-time information in IR and color. This information permitted timely decisions to be made and the results of those decisions to be reviewed with the subsequent fly-over zone site. Various agencies involved in the process were able to see and verify the results of the cleanup process (ARCO, 1998).

To insure safe operation, pipeline operators would follow the appropriate American Petroleum Institute recommended practices. They would inspect the pipelines regularly to determine if any damage was occurring and would also perform preventative maintenance. Preventive maintenance includes installing improved cathodic protection, using corrosion inhibitors and continuing regular visual inspections.

No oil or gas may be transported until the operator has obtained the necessary permits and authorizations from federal, state, and local governments. ADNR and other state, federal, and local agencies will review the specific transportation system when it is actually proposed.

Mitigation Measures

The following are summaries of some applicable mitigation measures designed to mitigate potential impacts from oil and gas transportation. For a complete listing of mitigation measures and licensee advisories see Chapter Seven. Additional, site-specific and project-specific mitigation measures may be imposed as necessary if exploration and development take place.

- Oil Spill Prevention and Control – Licensees are advised they must prepare contingency plans addressing prevention, detection, and cleanup of oil spills. Lining, diking and buffer zones are required to separate oil storage facilities from marine and freshwater supplies.
- Wherever possible, pipelines must utilize existing transportation corridors and be buried where soil and geophysical conditions permit. In areas where pipelines must be placed above ground, pipelines must be sited, designed, and constructed to allow free movement of moose and other terrestrial animals.
- Oil pipelines must be located upslope of roadways and construction pads and must be designed to facilitate the containment and cleanup of spilled hydrocarbons. Pipelines, flow lines, and gathering lines must be designed and constructed to assure integrity against climatic conditions and other geophysical hazards.